Strange Quark Contributions to the Proton

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Overview

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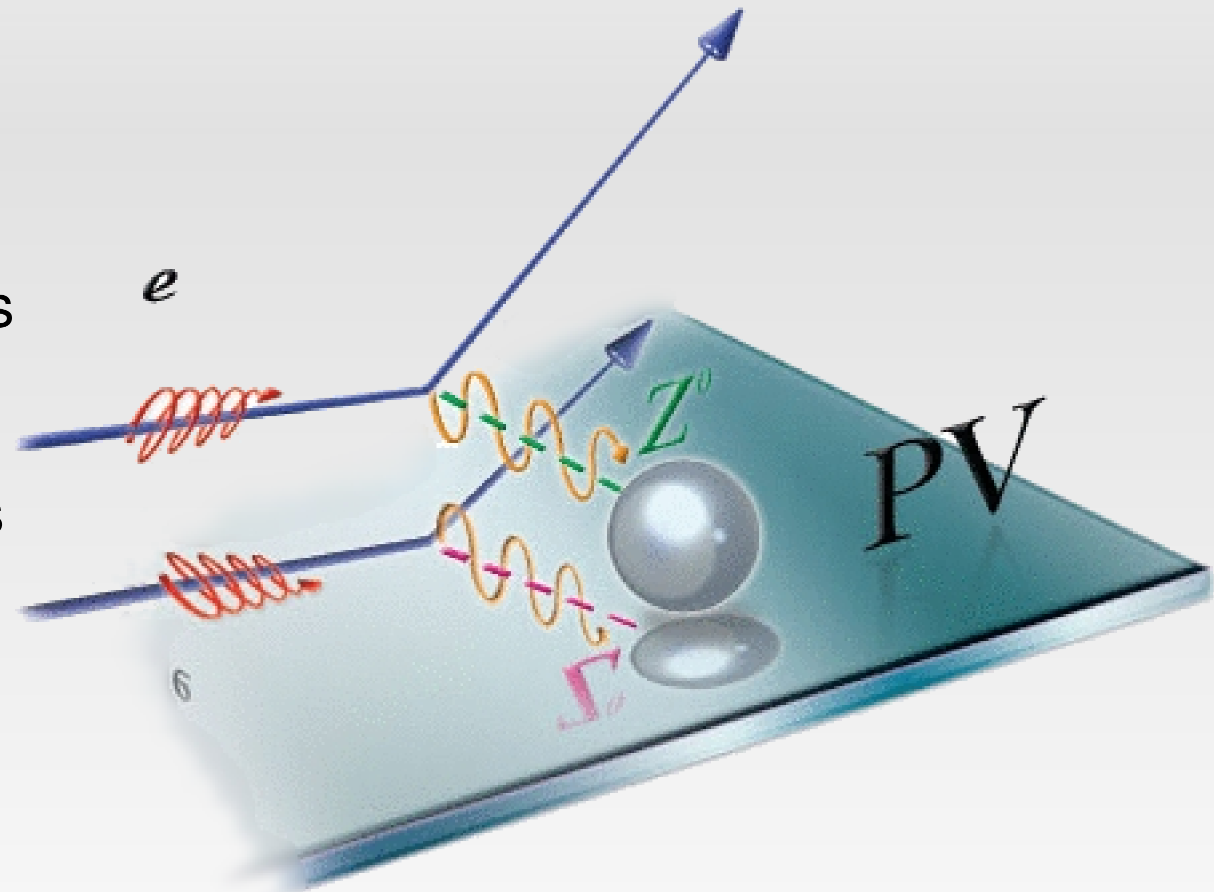
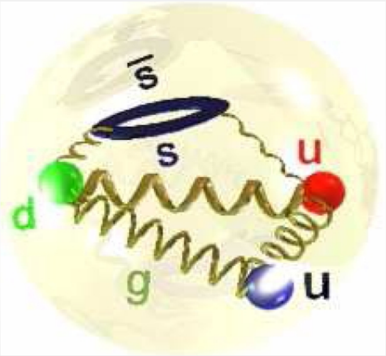


Motivation

- In the naive Quark Model, the proton is composed of 2 up quarks and a down quark
- These three quarks only account for 1% of the proton's mass and ~30% of its spin
- There must be ”other stuff” → The proton's sea
- Strange quarks are only present in the sea

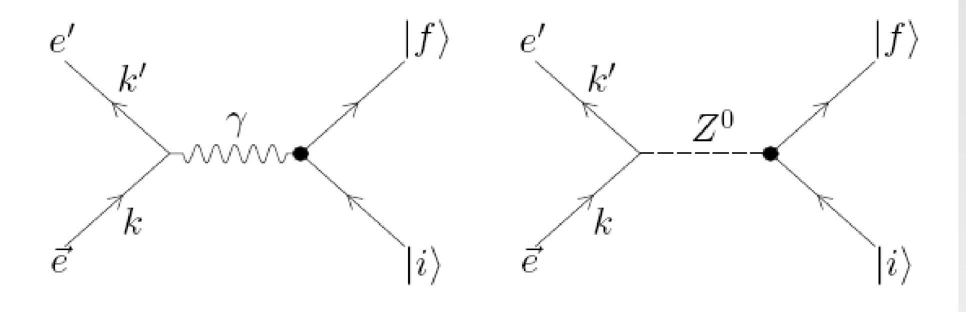


Theory

- Measure the Parity-Violating Asymmetry

$$A^{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L}$$

- The primary contributing Feynman Diagrams:



- This asymmetry becomes:

$$= \frac{|\mathcal{M}^\gamma + \mathcal{M}^Z_R|^2 - |\mathcal{M}^\gamma + \mathcal{M}^Z_L|^2}{|\mathcal{M}^\gamma + \mathcal{M}^Z_R|^2 + |\mathcal{M}^\gamma + \mathcal{M}^Z_L|^2}$$

$$= -\frac{G_F Q^2}{4\pi\alpha\sqrt{2}} \left[\frac{\epsilon G_E^{\gamma p} G_E^{Zp} + \tau G_M^{\gamma p} G_M^{Zp} - (1 - 4\sin^2\theta_W)\epsilon' G_M^{\gamma p} G_A^{Zp}}{\epsilon (G_E^{\gamma p})^2 + \tau (G_M^{\gamma p})^2} \right]$$

Where is the Strange Quark?

- Can write the Proton's Form Factor as:

$$G^{\gamma p}_{E,M} = \frac{2}{3}G^{u}_{E,M} - \frac{1}{3}G^{d}_{E,M} - \frac{1}{3}G^{s}_{E,M}$$

- Using Isospin symmetry, can write the Neutron's Form Factor as:

$$G^{\gamma n}_{E,M} = \frac{2}{3}G^{d}_{E,M} - \frac{1}{3}G^{u}_{E,M} - \frac{1}{3}G^{s}_{E,M}$$

- Similarly the Weak Form Factor can be written as:

$$G^{Zp}_{E,M} = (1 - \frac{8}{3}\sin^2\theta_W)G^{u}_{E,M} + (-1 + \frac{4}{3}\sin^2\theta_W)(G^{d}_{E,M} + G^{s}_{E,M})$$

The Asymmetry becomes

$$= -\frac{G_F Q^2}{4\pi\alpha\sqrt{2}} \times \left\{ \left(1 - 4\sin^2\theta_W\right) - \frac{\epsilon G_E^p G_E^n + \tau G_M^p G_M^n}{\epsilon \left(G_E^p\right)^2 + \tau \left(G_M^p\right)^2} - \frac{\epsilon G_E^p G_E^s + \tau G_M^p G_M^s}{\epsilon \left(G_E^p\right)^2 + \tau \left(G_M^p\right)^2} \right.$$

$$\left. + \frac{2\epsilon' \left(1 - 4\sin^2\theta_W\right) G_M^p G_A^{Zp}}{\epsilon \left(G_E^p\right)^2 + \tau \left(G_M^p\right)^2} \right\}$$

- A^{PV} ranges from approximately -1 part per million (ppm) at Q^2 =0.1 GeV^2 to about -50 ppm at Q^2 =1.0 GeV^2 for typical CEBAF energies.

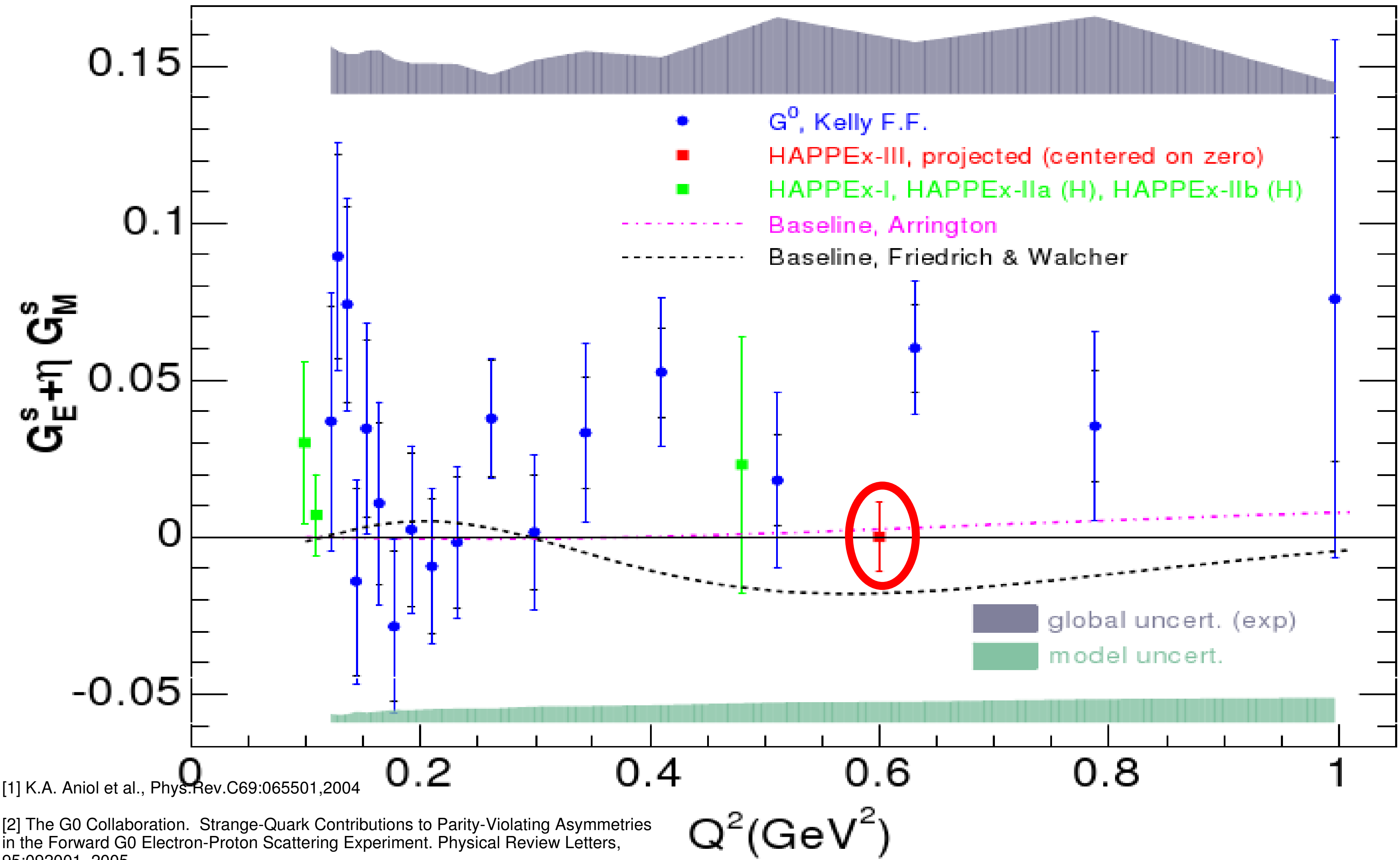
What does this mean?

- If G_E^s is zero, the strange and anti-strange quark have no radial separation
- If G_M^s is zero, the strange and anti-strange quark are produced with their spins parallel and again have no radial separation

Experiment Specifications

- We will measure the parity-violating asymmetry of 3.4 GeV elastically scattered electrons from a liquid Hydrogen target at $\langle Q^2 \rangle = 0.6\ \mathrm{GeV}^2$
- $G^s_E + 0.48\, G^s_M$ will be measured to a precision of ± 0.011
- If the results match the central value of presently existing world data, this precision represents four standard deviations from zero

Previous Experiments



[1] K.A. Aniol et al., Phys.Rev.C69:065501,2004

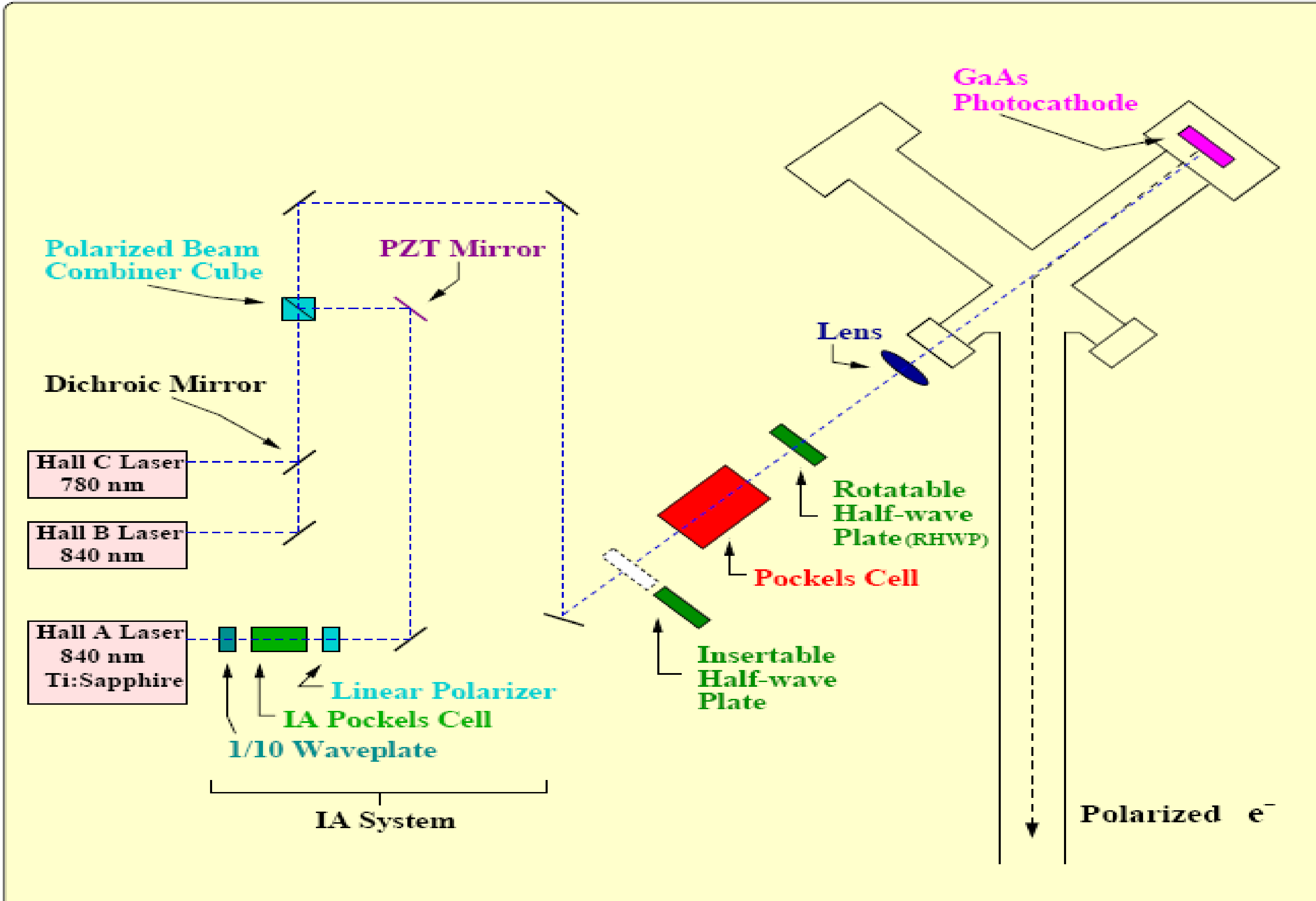
[2] The G0 Collaboration. Strange-Quark Contributions to Parity-Violating Asymmetries in the Forward G0 Electron-Proton Scattering Experiment. Physical Review Letters, 95:092001, 2005

[3] K.A. Aniol et al., Phys.Lett.B635:275-279,2006

Experimental Technique

- The Jefferson Lab Polarized Source will be used to produce electrons with high polarization (~85%) at high current (100 µA)
- 20 cm LH_2 target → high luminosity
- Uses Hall A High Resolution Spectrometers (HRS) to focus elastically scattered electrons an integrating detector

The Injector



Hall A

- Compton Polarimater
  - Allows continuous polarization measurement
- Luminosity Monitors
  - Very low angle detectors whose singal is dependent on beam position, beam intensity, and target density
- High Resolution Spectrometers
  - Gives a momentum resolution of 10^{-4}

Experimental Challenges

- No expected problems with absolute precision or controlling false asymmetries
- Main challenge is reaching the fractional systematic error: 1.4%
  - Main challange right now if to measure the beam polarization to within 1% (see talk by Abdurahim Rakhman)

Conclusion

- HAPPEx-III will be measuring the parity-violating asymmetry and will use it to find the strange quark's contributions to the proton's electric and magnetic form factors
- Use the injector and Hall A to make a high precision measurement
- Give insight about how the proton's sea contributes to its form factors.